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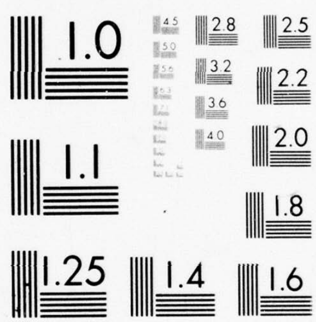
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MANUFACTURING METHODS AND TECHNOLOGY
FOR HERMETICALLY SEALED LITHIUM
SO_2 CELL BATTERIES

4TH QUARTERLY REPORT FOR PERIOD
1 APRIL 1977 TO 30 JUNE 1977

CONTRACT #DAAB07-76-C-0042

JULY 1977

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Effort has continued on the Manufacturing Methods and Technology Program to establish and evaluate the fabrication techniques and automation processes required to attain hardware production levels as specified in the subject contract. Fabrication and testing of hermetic cell prototypes under the required thermal discharge profiles has continued to demonstrate the feasibility of each cell design and to define cell over

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performance and safety characteristics. Complete drawing packages, specifications and detailed bill of material are presently being developed to define the dimensional characteristics of each cell/battery and insure proper configuration control. Hermetic sealing of the cell periphery has been successfully implemented on all required cell sizes (.550 inch to 1.500 inch diameter) using an arc welding process with no thermal damage to adjacent components. Incorporation of an additional arc welding station will permit attainment of the required production rate goal of 5000 units per day.

The first prototype core winder has been modified to permit the fabrication of cores utilizing a non-woven polypropylene separator as used in the BA-5598, BA-5100 and BA-5842 cells. Evaluation of various sub-contractors is presently underway for the procurement of a 2nd core winder, anode machine and electrolyte preparation and dispensing equipment. Production fabrication and testing of continuous cathodes has been successfully demonstrated on various cathode formulations and the fabrication of the ancillary drying modules and slitting station is currently in progress. A detailed process flow chart was developed to aid in the integration of the automated fabrication equipment within an operational production line.

TECHNICAL REPORT 0042-Q-04 JULY 1977

MANUFACTURING METHODS AND TECHNOLOGY FOR HERMETICALLY SEALED LITHIUM SO_2 CELL BATTERIES

FOURTH QUARTERLY REPORT

1 APRIL 1977 TO 30 JUNE 1977

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U.S. ARMY ELECTRONICS COMMAND, Fort Monmouth, N.J. 07703

ABSTRACT

Effort has continued on the Manufacturing Methods and Technology Program to establish and evaluate the fabrication techniques and automation processes required to attain hardware production levels as specified in the subject contract. Fabrication and testing of hermetic cell prototypes under the required thermal discharge profiles has continued to demonstrate the feasibility of each cell design and to define cell performance and safety characteristics. Complete drawing packages, specifications and detailed bill of material are presently being developed to define the dimensional characteristics of each cell/battery and insure proper configuration control. Hermetic sealing of the cell periphery has been successfully implemented on all required cell sizes (.550 inch to 1.500 inch diameter) using an arc welding process with no thermal damage to adjacent components. Incorporation of an additional arc welding station will permit attainment of the required production rate goal of 5000 units per day.

The first prototype core winder has been modified to permit the fabrication of cores utilizing a non-woven polypropylene separator as used in the BA-5598, BA-5100 and BA-5842 cells. Evaluation of various sub-contractors is presently underway for the procurement of a 2nd core winder, anode machine and electrolyte preparation and dispensing equipment. Production fabrication and testing of continuous cathodes has been successfully demonstrated on various cathode formulations and the fabrication of the ancillary drying modules and slitting station is currently in progress. A detailed process flow chart was developed to aid in the integration of the automated fabrication equipment within an operational production line.

PURPOSE

The basic objectives of this program are to:

a) establish the producibility of the specified hermetically sealed lithium cells and batteries by mass production techniques and facilities;

b) establish and improve quality control surveillance and inspection;

c) initiate process improvements to minimize overall fabrication costs and time.

The program consists of six (6) primary tasks:

- Battery and Cell Design
- Electrolyte Preparation and Dispensing System
- Core Winding Machine Design
- Cathode Manufacture
- Anode Manufacture
- Welding Equipment Design

Evaluation of the above independent tasks will be conducted in parallel to permit subsequent integration within an operational manufacturing process.

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I. INTRODUCTION

The Manufacturing Methods and Technology (MM&T) Project No. 2759371 to Establish Automatic Electrode Production for Lithium Hermetic Cells requires the establishment of production techniques for hermetic lithium cell components, cells and batteries to meet production levels delineated in the contract. Specifically, the following hermetic batteries will be manufactured utilizing the automatic electrode processes established under this program:

BA-5590 ( )/U	BA-5574 ( )/U
BA-5585 ( )/U	BA-5841 ( )/U
BA-5090 ( )/U	BA-5100 ( )/U
BA-5842 ( )/U	BA-5567 ( )/U
BA-5568 ( )/U	BA-5598 ( )/U

The production engineering goals of this program are to perform the necessary design, development, engineering, fabrication of special tooling and construction of test facilities and limited production equipment to obtain confirmatory sample approval; and to establish a pilot line and pilot run for the purpose of demonstrating a manufacturing process.

As a result, Power Conversion, Inc. will establish a Pilot Line and demonstrate the capability of this line with at least 20% of the Pilot Run units. The rates to be met are:

5,000 "D" Type Cells in an eight-hour day.

2,500 cells other than "D" Type* cells in an eight-hour day.

*Other than "D" type cells are those cells to be utilized in the fabrication of the deliverable batteries.

II. PROGRAM EVALUATION AND REVIEW TECHNIQUE

The PERT Chart, as shown in Figure 1, has been revised and updated to reflect the present program status. Specific problem areas were defined and reviewed with respect to meeting the overall program objectives on a timely basis. Priorities have been restructured in order to minimize the impact of such delays on the contract target completion dates.

The major areas of revision are summarized as follows:

Cell Design - Additional time has been allocated to permit modification of the electrode design configuration and cell construction in an effort to meet capacity and start-up requirements; especially for the BA-5567, BA-5568 and BA-5090 cells. In addition, an overview of the lithium/sulfur dioxide stoichiometric ratios has been performed to insure, where possible, the use of a properly balanced cell structure which will enhance the overall safety, reliability and thermal efficiency of the required batteries.

Battery Design/Engineering Samples - Various alternatives are presently being investigated to facilitate the fabrication of the BA-5100, BA-5567, BA-5568 and BA-5090 batteries within the required dimensional, material and performance specifications. Additional time has been allocated for the production of sixty-six (66) Engineering Battery Samples of each type to conform with the additional effort required to finalize the cell design and process specifications and to fabricate ten (10) cell prototypes of each battery type per CLIN 0006 of the contract. Prototypes for six (6) battery types have been completed and evaluated to date.

2nd Core Winder/Anode Machine - Additional time has been allocated to permit design integration of the 2nd core winder and anode machine, the concept of which is to provide continuous anode feed, electrical tabbing and core winding of the electrode assembly. Previous designs required manual loading of pre-cut anodes within the core winder.

Several problem areas have been resolved during this quarterly period with respect to the following:

. Arc Welding - Localized porosity at the peripheral seal has occurred during the arc welding process due to inadequate control of the nickel plating composition and thickness at the joint interface. This condition will be corrected by the implementation of a detailed plating specification to insure use of the proper formulation and processes. In addition,

Contract No. DAAB07-7

Program Evaluation and Review

(PERT/TIME)

KEY:

B = Battery Cell design

F = Electrolyte Fill system Design

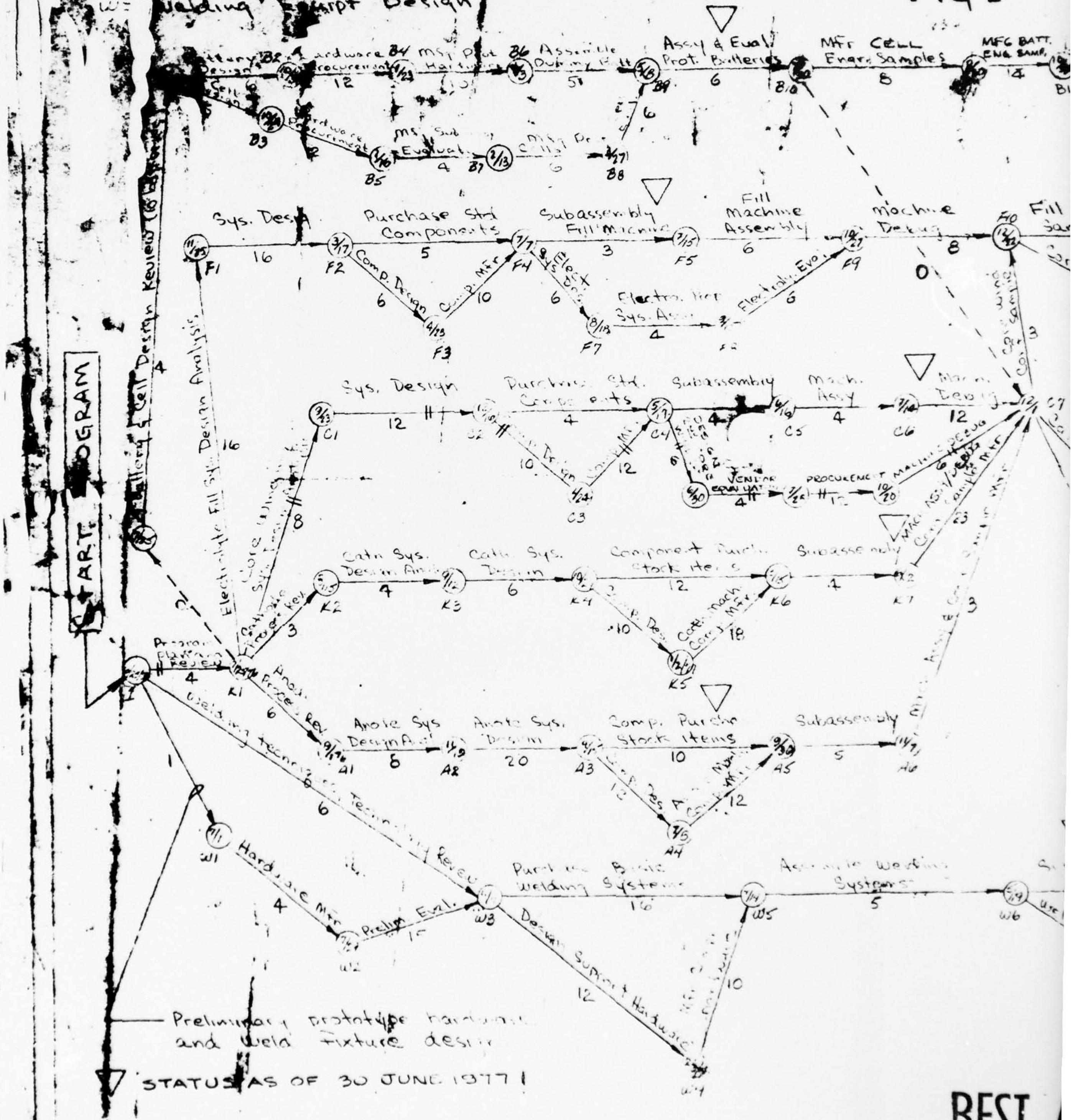
C = Core Winding machine Design

K = Cathode mfg machine Design

A = Anode mfg Machine Design

W = Welding Equipt Design

FIG 1



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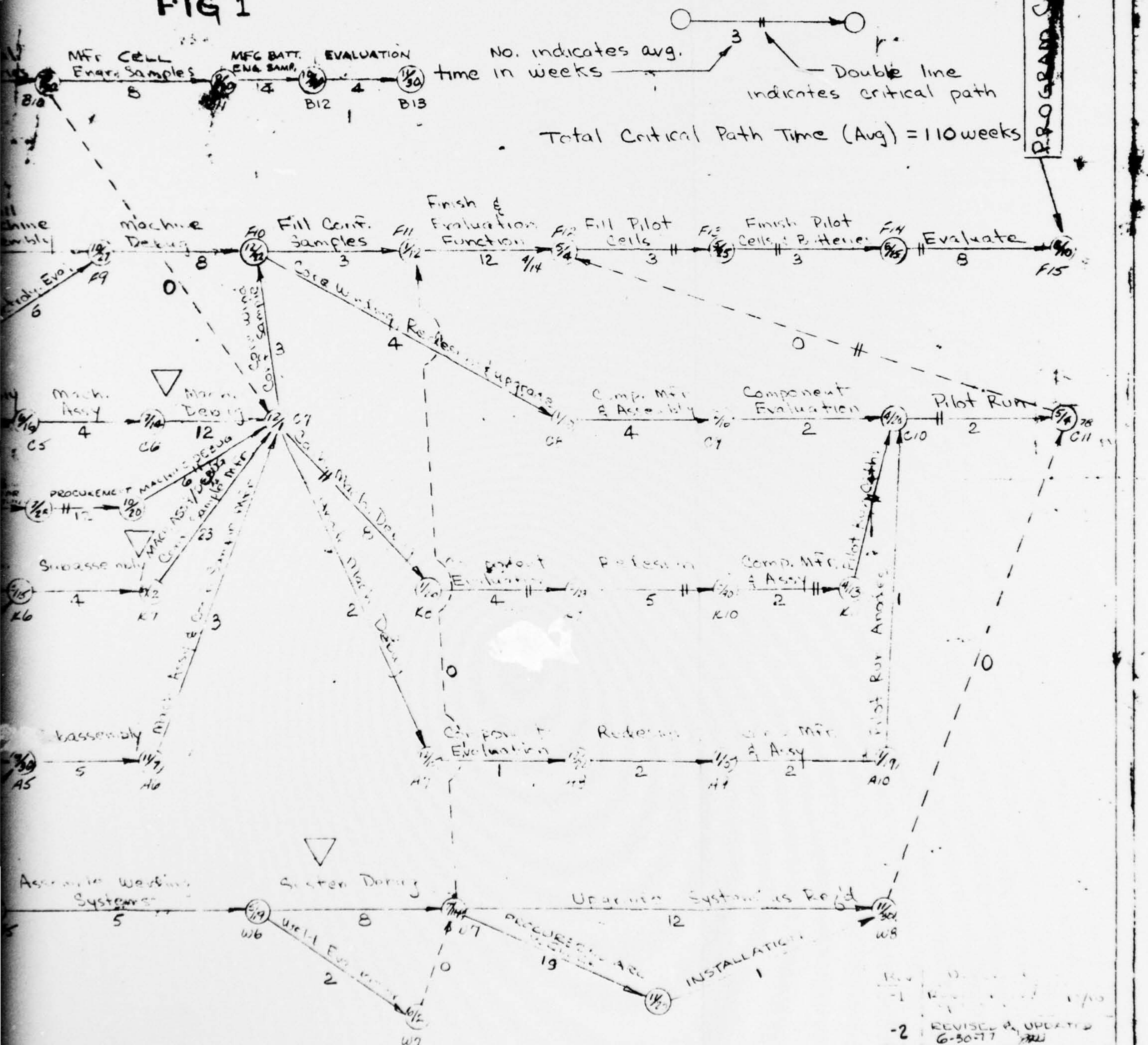
Evaluation and Review Technique
(PERT/TIME) CLIN 0002

Power Conversion Inc
Mt Vernon New York
July 1976

FIG 1



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no evidence of thermal damage **has** been observed immediately after the peripheral welding of cell sizes ranging from .550 inch to 1.500 inch diameter.

. Resistance Welding - A 30 KVA resistance welder has been installed at PCI to permit hermetic welding of the glass seal assembly to the top shell structure at a rate of 3000 units/day. Evaluation of yield rates and throughput studies will be accomplished during the next reporting period.

. BA-5567/BA-5568 Cell Design - Difficulty in the construction of these cells have been encountered due to the restricted dimensional and performance envelope. Use of a bottom fill port and a flat top shell construction is presently being evaluated as an alternative to minimize assembly problems and optimize cell operational efficiency.

Periodic review of the PERT chart will be continued during the next quarterly period in order to identify any additional problem areas or modifications as they occur. Such action will permit timely corrective action and will avoid serious delays during cell/battery assembly and equipment manufacture and evaluation.

III. CELL AND BATTERY DESIGN

A. Cell Design

The electrode configurations and internal construction of some cell designs have been modified as a result of additional electrical discharge performance data, theoretical internal volume analysis and re-evaluation of lithium/sulfur dioxide ratios. The revised cell electrode characteristics are summarized in Table 1.

The electrochemical proportions of each required cell type has been reviewed to determine the Li/SO_2 ratio; a summary of which is presented in Table 2. Such data will be used to stoichiometrically balance the proportion of lithium to sulfur dioxide at a maximum ratio of 1.2 to minimize the hazards which may be experienced under specific abuse test environments; especially during forced reverse discharge at moderate to high current levels.

A summary of the discharge profiles and service life requirements of each required cell type is presented in Table 3.

B. Cell Prototype Fabrication

Hermetic cell prototypes are presently being constructed to verify proper dimensional conformance and electrical performance under the required thermal discharge profiles. Ten (10) cell samples of the following battery types were submitted in accordance with CLIN 0006 of the contract:

- BA-5590
- BA-5842
- BA-5598
- BA-5100
- BA-5574
- BA-5841

Several problem areas have been resolved during this quarterly period with respect to the following:

BA-5090/BA-5585 CELLS - Difficulty has been encountered during the peripheral welding operation using the arc welding process due to porosity at the welded joint interface. This condition has been attributed to the physical configuration of the nickel plating present on the surface of the can and top shell at the joint interface. Several nickel plating processes are currently being evaluated in an effort to define the optimal process. These include electroless plating, electro plating, sulfamate nickel plating and Watts plating deposited on material either prior to or immediately after forming. A detailed specification will be developed upon selection of the optimal process to define the process and the nickel bath composition.

TABLE 1

CELL ELECTRODE CHARACTERISTICS

BATTERY TYPE		5598	5100	5590	5842	5585	5567	5568	5841	5574	5090
ANODE											
Length	(inch)	23.5	23.5	23.5	11.5	16.5	11.5	10.0	5.0	5.0	4.0
Width	(inch)	1.375	.562	1.625	1.625	1.625	.200	.200	2.125	.750	.500
Thickness	(inch)	.012	.012	.010	.019	.008	.012	.012	.010	.010	.010
Weight (gm)		3.4	1.4	3.3	3.1	1.9	.24	.21	.93	.33	.18
CATHODE											
Length	(inch)	24.0	24.0	24.0	12.0	17.0	12.0	10.5	5.5	5.5	4.5
Width	(inch)	1.375	.562	1.625	1.625	1.625	.200	.200	2.125	.750	.500
Thickness	(inch)	.033	.033	.025	.040	.020	.033	.033	.025	.025	.025
ELECTROLYTE											
Weight (gm)		36.5	18.3	34	34	15	4.5	3.5	7.5	4.0	2.5
CELL WEIGHT (gm)		87	37	84	84	58	12	12	23	12	7
CURRENT REQUIREMENTS (amps)		.95 .048	.093	3.0 .64 .05	.175	3.0 .64 .05	.056	.090	.12	.115	.013
CATHODE SURFACE AREA (cm^2)		426	174	503	252	356	31	27	151	53	29
CURRENT DENSITY LEVEL (ma/cm^2)		2.23 .11	.53	6.0 1.3 .10	.69	8.43 1.8 .14	1.81	3.33	.79	2.17	.45

TABLE 2

CELL ELECTRODE ANALYSIS

BATTERY TYPE	ANODE WEIGHT (GRAMS)	THEORETICAL ANODE CAPACITY	ELECROLYTE WEIGHT (GRAMS)	THEORETICAL CAPACITY	Li/SO_2 RATIO	LITHIUM		
						LENGTH	WIDTH	THICKNESS
BA-5100	1.3883	5.3589	18.5000	5.3102	1.0091	23.5	0.5625	.012
BA-5598	3.3936	13.0996	36.0102	10.3363	1.2673	23.5	1.375	.012
BA-5842	3.1075	11.9956	32.000	9.1852	1.3059	11.5	1.625	.019
BA-5590	3.3422	12.9011	32.1345	9.2238	1.3986	23.5	1.625	.010
BA-5585	1.8773	7.2466	20.7500	5.9560	1.2166	16.5	1.625	.008
BA-5567	0.3019	1.1655	3.7000	1.0620	1.0974	11.5	0.250	.012
BA-5568	0.2625	1.0135	3.2375	0.9292	1.0907	10.0	0.250	.012
BA-5574	0.3610	1.2669	3.8000	1.0907	1.1615	5.00	0.750	.010
BA-5841	0.9299	3.5895	9.000	2.5833	1.3895	5.00	2.125	.010
BA-5090	0.1750	0.6756	2.000	0.5740	1.1770	4.00	0.500	.010

CELL PERFORMANCE REQUIREMENTS

CELL TYPE	CELL DISCHARGE PROFILE	CUT-OFF VOLTAGE	SERVICE REQUIREMENTS (HOURS)			CAPACITY @ +70°F (A.H.)
			+70°F	+130°F	-20°F	
BA-5598	2.84Ω @ 2 MIN. 58.2Ω @ 18 MIN.	2.0	50	50	35	6.91
BA-5100	30Ω CONT.	2.225	40	37	21	3.73
BA-5590	0.8Ω @ 100 MS 3.9Ω @ 1 MIN. 56Ω @ 9 MIN	2.0	48	42	24	5.26
BA-5842	175 MA CONT	2.0	48	42	24	8.4
BA-5585	0.8Ω @ 100MS 3.9Ω @ 1 MIN 56Ω @ 9 MIN	2.0	24	21	12	2.63
BA-5567	50Ω CONT	2.0	20	18	12	1.12
BA-5568	30Ω CONT	2.0	12	10	7	1.08
BA-5841	22.5Ω CONT	2.2	15	13	8	1.8
BA-5574	23.5Ω CONT	2.0	8	7.5	.4	.919
BA-5090	212Ω CONT	2.0	55	50	30	.726

Table 3

BA-5567/BA-5568 CELLS - An alternative design utilizing a bottom fill port and a flat reinforced top structure as shown in Figure 2 has been designed to permit conformance to the required dimensional specifications and performance requirements. Components will be procured during the next reporting period.

Preliminary discharge tests have been performed on the following hermetic prototypes during this quarterly period:

BA-5100 CELL

Discharge Profile: 30 ohms continuous

Discharge Temperature (°F)	Required Service @ 2.25 volts (hours)	Actual Service @ 2.25 volts (hours)	Average Output Voltage (volts)
+70	40	41.8	2.85

BA-5574 CELL

Discharge Profile: 23.5 ohms continuous

Discharge Temperature (°F)	Required Service @ 2.0 volts (hours)	Actual Service @ 2.0 volts (hours)	Average Output Voltage (volts)
+70	8	7.4	2.80

BA-5841 CELL

Discharge Profile: 22.5 ohms continuous

Discharge Temperature (°F)	Required Service @ 2.2 volts (hours)	Actual Service @ 2.2 volts (hours)	Average Output Voltage (volts)
+70	15	16.6	2.80

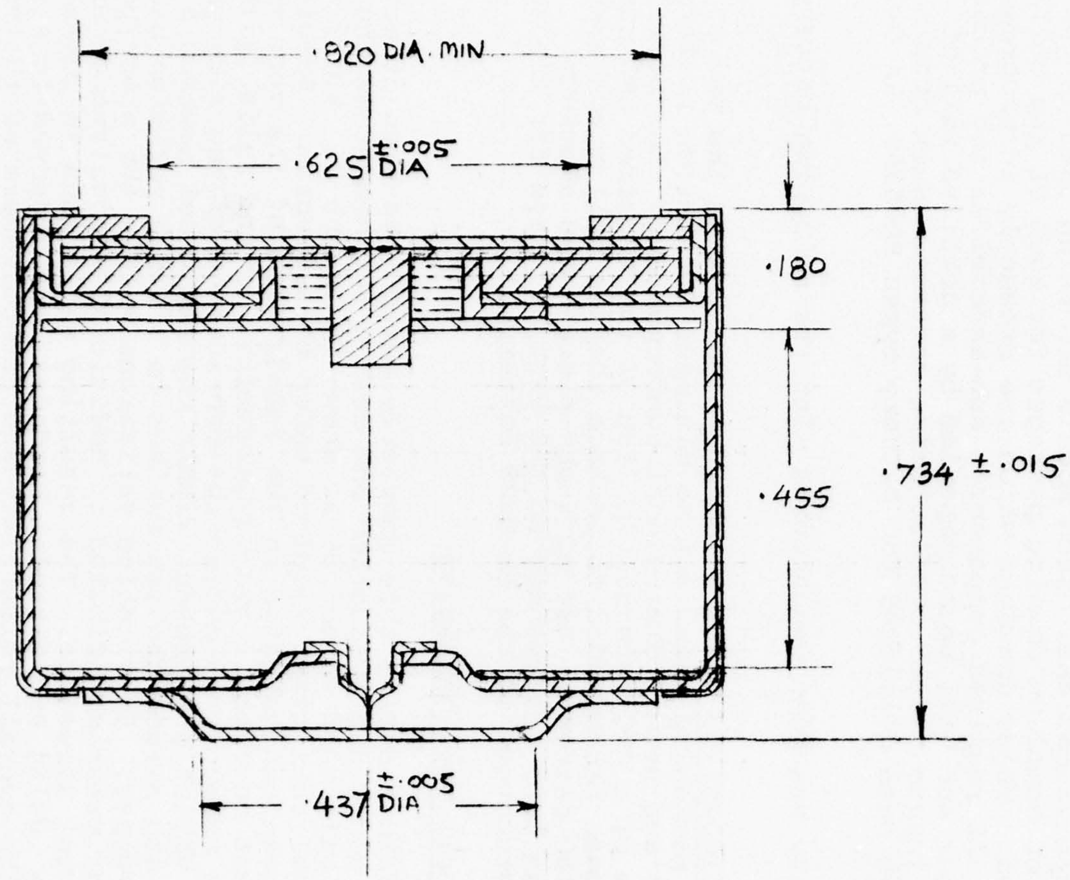


Figure 2

BA-5567 BATTERY DESIGN

C. Battery Prototype Fabrication

Prototype hermetic battery models are presently being constructed and finalized to verify conformance to all dimensional and weight specifications. Such models are being used in the development of complete drawing packages for each of the cell/ battery types. These drawings which are presently in progress will define all required components, sub-assemblies and process specifications and will be accompanied by a detailed bill of material to insure proper configuration control. Such drawing packages have been completed for battery types BA-5598, BA-5842 and BA-5590.

Difficulty has been encountered with the following battery types:

BA-5100/BA-5090 - PCI has proposed to ECOM the use of alternative packaging materials to minimize insulation resistance difficulties and permit dimensional conformance to the specification. Use of a PVC external in lieu of the required CRS material jacket has been recommended to package the two cell stack structure of the BA-5100 battery. Use of a one piece drawn aluminum enclosure has been recommended as the external case for the three cell stack structure of the BA-5090 battery.

D. Cell Vent Mechanism

Effort during this quarterly period has been directed towards the continued evaluation and design refinement of the coined side wall vent structure as shown in Figure 3, which will be used on all cell sizes required under this program. Specifically effort has been concentrated on the fabrication of the vent mechanism and its effect on overall vent reproducibility and reliability. Difficulties were encountered during the fabrication of the side wall vent due to variations present within the fly wheel powered press which coins and swages the can surface to a fixed position using an impact process. Lubrication variations within the piece part and the power press contributed to additional inconsistency of the coined vent structure. The resulting variations in coined thickness ($\pm$ .0015) and material hardness were observed to seriously compromise the overall reliability and effectiveness of the vent mechanism during large quantity fabrication runs. Variations in hydraulic pressure relief values were found to exceed a tolerance of $\pm$ 50 psig which is considered unacceptable within the Li/SO_2 system. In addition, evidence of porosity at the coined interface was observed on small diameter cells (less than 1.0 inch) where a coined thickness of .002 to .003 inch is required to permit vent activation at approximately 400 psig.

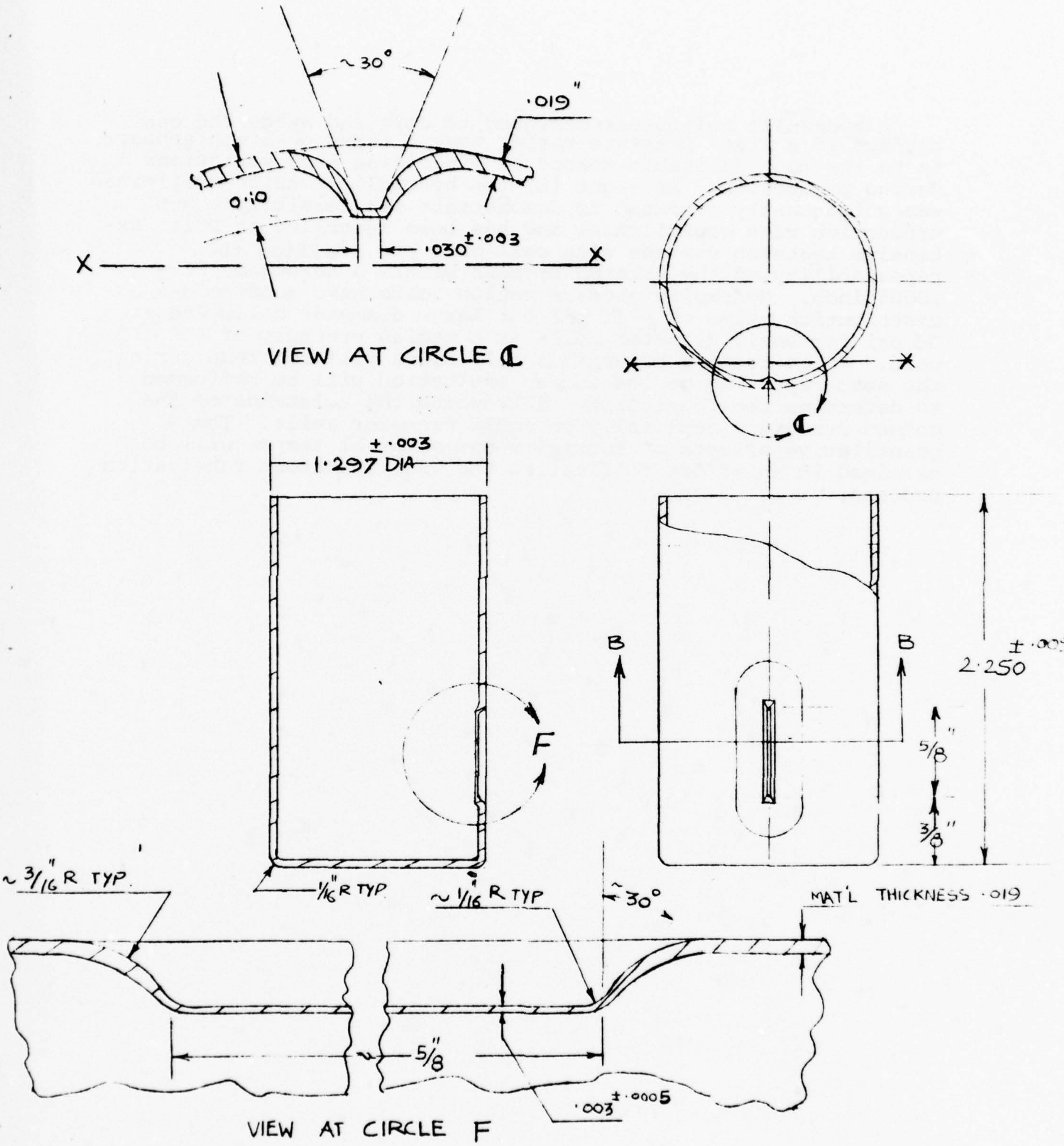


FIGURE 3

SAFETY VENT MECHANISM

A hydraulic multipress designed to coin and swage the can surface at a fixed pressure rather than a fixed position appears to be the most desirable method of minimizing such variations during production. An eight (8) ton hydraulic Dension Multipress was subsequently procured to demonstrate its feasibility and production rate capabilities and has been installed at PCI. Extensive tests on various size cell cans has verified the repeatability of the coining process within a tolerance of ± .0005 inch. Hydraulic pressurization tests have confirmed a distribution value of ± 50 psi for large diameter cells and ± 75 psi for small diameter cells at a median pressure of 400 psig. Abuse testing of various cell sizes will continue during the next reporting period and an evaluation will be performed to determine the feasibility of reducing the tolerance of the coined structure especially on small diameter cells. The quantitative effects of lubricity and material temper will be examined in an effort to finalize the vent structure fabrication process.

IV. ANODE FABRICATION

Effort has been directed during this quarterly period toward determining the design feasibility of continuous anode preparation and its subsequent interface with the input of the core winder. Continuous anode fabrication is considered to be the preferred approach because of the difficulties encountered during manual handling, cutting, storage and transfer of the anode due to the extreme ductility and adherence characteristics of lithium foil. Physical distortion of the anode/tab assembly results in significant delays during subsequent electrode loading within the core winder feed station.

The design concept for such continuous anode fabrication is summarized below and is illustrated in Figure 4:

- Continuous lithium foil will be transferred from the feed coil supply to a preumatic tab staking station. Edge control guidance will be provided to assure proper alignment and registration of the lithium foil.

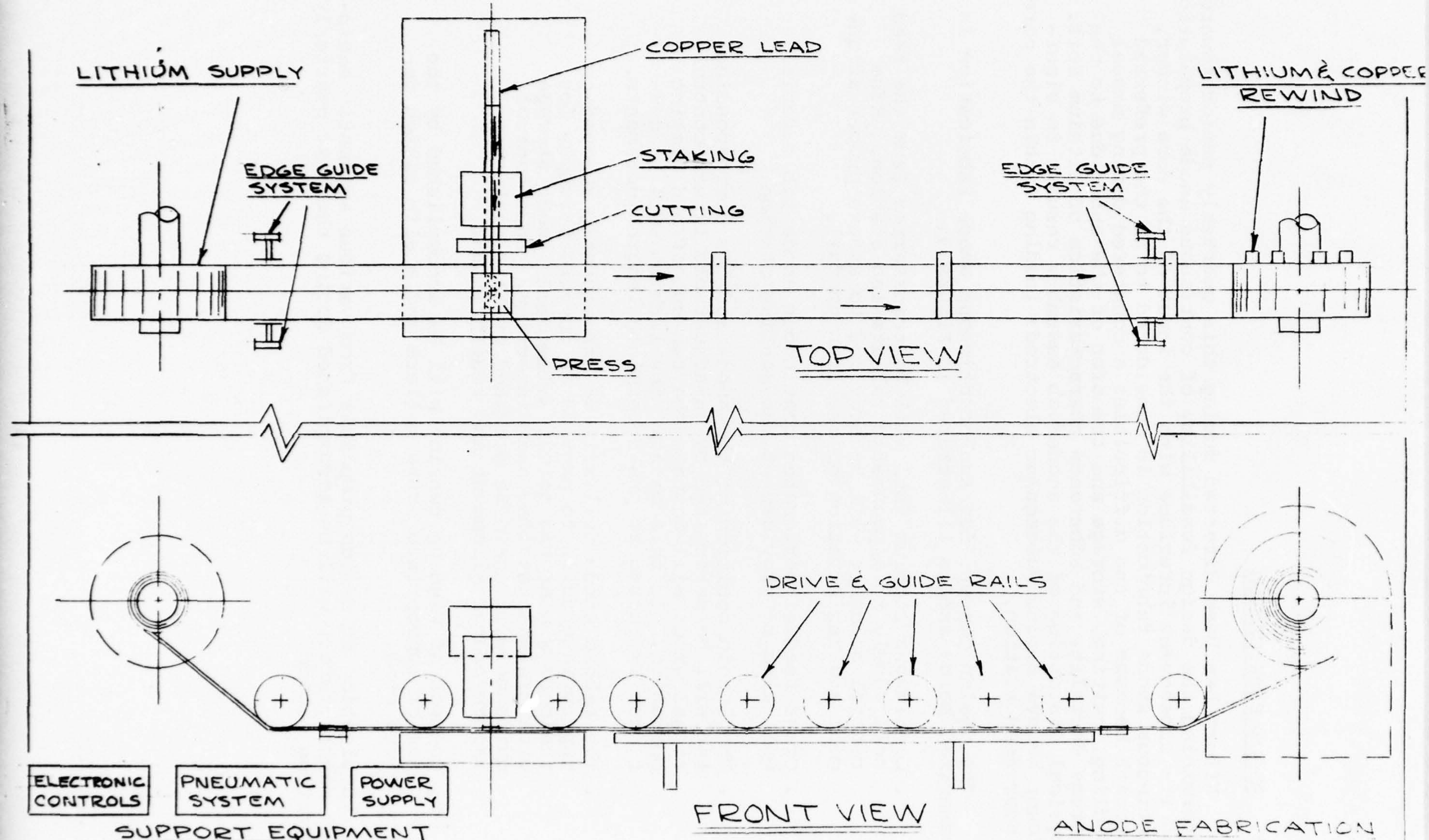
- Cross feed of perforated continuous anode tab material will also be provided at the staking station.

- The length position of the anode and its corresponding tab will be determined by an adjustable linear control signal which will actuate the tab cutoff and staking operation. In this manner, the lithium will be continuously tabbed at pre-determined length increments.

- The tabbed anode foil will be subsequently rewound on appropriate coils to provide an inventory supply for the core winder and permit subsequent anode storage with minimal handling and distortion. Edge control guidance will again be provided at this station to assure proper alignment and registration.

- Control of winding tension will be accomplished by the use of appropriate drive rollers and a slip clutch rewind coil.

Evaluation of design proposals from various automatic equipment manufacturers will be accomplished during the next quarterly reporting period.



ANODE FABRICATION
FIGURE 4

V. CATHODE FABRICATION

Work during this quarterly period has been directed towards continued development and evaluation of an operational continuous cathode fabrication machine. Additional prototype cathodes have been fabricated to determine the relationship of the machine parameters (gap height, belt speed, slurry viscosity, drying speed) with respect to the physical characteristics of the cathode (cathode thickness and uniformity, porosity, density, adhesion characteristics).

CATHODE THICKNESS/UNIFORMITY

Effort was directed towards the finalizing of machine parameters on cathodes required for the BA-5842, BA-5598 and BA-5100 cells. Reservior, mixing and drying equipment has been installed to permit fabrication of larger cathode batches and permit evaluation of machine performance over extended periods of operation.

Cathode thickness is controlled by the viscosity of the slurry, belt speed, feed rate and the height setting of the sizing rollers. Feed rate is primarily controlled by the blade gap which controls the transfer of slurry material to the belt.

A thirty (30) gallon reservoir and slurry mixer was installed to prepare the raw cathode mix into a homogeneous slurry of the desired viscosity (approximately 1750 cps).

Machine parameters were subsequently developed for the following cathode types and are summarized below:

Cathode Thickness (inch)	Allowed Tolerance (inch)	Blade Gap (inch)	Belt Speed (feet/min)	Cathodes Per Day
.0375	± .0025	9/64	1½	5040
.0325	± .0025	1/8	1½	2520

The above parameters permit attainment of the desired cathode thickness prior to its entry within the sizing roller to avoid subsequent material densification. The function of the sizing roller is merely to distribute and smooth the deposited slurry uniformly across the width of the cathode sheet to avoid excessive densification and the resulting variations in porosity.

The fabrication and evaluation of approximately 15,000 cathodes of each of the aforementioned thicknesses using 30 gallon batches is presently scheduled for the next reporting period. The test vehicle for the .0375 inch thickness cathode will be PCI Model 660-4-S cell (1 5/8 inch diameter, 2 inch height); for the .033 inch thickness cathode, it will be PCI Model 1500-2000 cell (1½ inch diameter, 2 inch height). Comparison studies will be performed on these cell types to quantitatively determine the overall performance characteristics with respect to the pre-existing cathode fabrication process.

In addition, a 250 gallon reservior and slurry mixer will be procured during the next quarterly period to further increase the size of the cathode batch. This mixer will provide continuous agitation of the slurry to insure homogeneity and prevent settling of the mix during transfer to the continuous belt.

CATHODE DRYING

A continuous cathode belt drying system has been installed at PCI to permit in process preliminary drying of the cathode sheet at the pre-established speed of the fabrication machine. Various drying techniques utilizing tunnel ovens, forced air convection chambers and radiant heating were evaluated to effectively dry the cathode without cracking or parching of the carbon surface; a condition primarily due to the presence of excess water content. The selected approach utilizes radiant heat energy under a predetermined thermal profile to remove such entrapped moisture prior to the slitting operation.

Continuous removal of the porous support substrate from the formed cathode will be reviewed during the next reporting period. This operation must be performed at a precise point in time to avoid localized removal of carbonaceous material from the aluminum conductor grid. Implementation of appropriate cooling cycles will be studied to determine the proper sequencing of substrate removal with respect to the overall fabrication process.

PREPARATION FOR CATHODE TABBING

Selective removal of cathode material along the width of the aluminum conductor grid is required to permit resistance welding of the aluminum cathode tab. Various techniques using pressurized water and/or air impingement were evaluated to determine the optimal process. The pressurized dry air impingement process was determined to be the preferred technique due to its simplicity and overall reproducibility. At present, a masking guide is manually placed over the cathode sheet to expose only the area to be removed. This area is subsequently impinged with approximately

80 $\pm$ 10 psi of dry air to remove all residual carbonaceous material. Various design concepts will be reviewed during the next reporting period to determine the feasibility of incorporating this operation into the automatic cathode fabrication process.

CATHODE SLITTING/TABBING

Various automatic shearing equipment is presently being investigated to permit precise cutting of the continuous cathode sheets in accordance with the pre-established length/width specifications. After the slitting operation, the cathodes would be transferred by a variable speed mechanically driven belt to the tabbing station for attachment of the aluminum cathode tab. Various techniques for welding the tab to the cathode structure will be evaluated during the next quarterly period and will include resistance welding, pressure welding and ultrasonic welding techniques.

VI. CORE WINDER

Effort has been directed during this quarterly period toward continued evaluation and modification of the first semi-automatic core winder presently installed within the humidity controlled dry room facility at PCI. In addition, considerable effort has been placed upon finalizing the optimal design concept for the 2nd core winder unit which will be interfaced with the continuous anode fabrication machine.

Evaluation of the first core winder has continued utilizing the electrodes for the BA-5842 and BA-5598 cells; both of which use non-woven polypropylene separator. Alignment guides have been installed along the feed station track to facilitate anode and cathode insertion and permit positive placement within the nibs of the drive rollers.

Difficulty has been encountered with alignment and registration of the cathode within the separator; especially on the 24 inch electrode version. This condition is primarily due to mis-alignment of the electrode along its width dimension; a result of a bias or slanted cut at the tab/electrode interface. When this occurs, the electrode feed into the split mandrel is not uniform and consequently shifts the far end of the electrode out of registration. This condition is worsened for longer electrode lengths. Effort will be directed to correct this problem during the next reporting period.

The design concept for the 2nd semi-automatic core winder is summarized below and is illustrated in Figures 5 and 6:

ELECTRODE POSITIONING

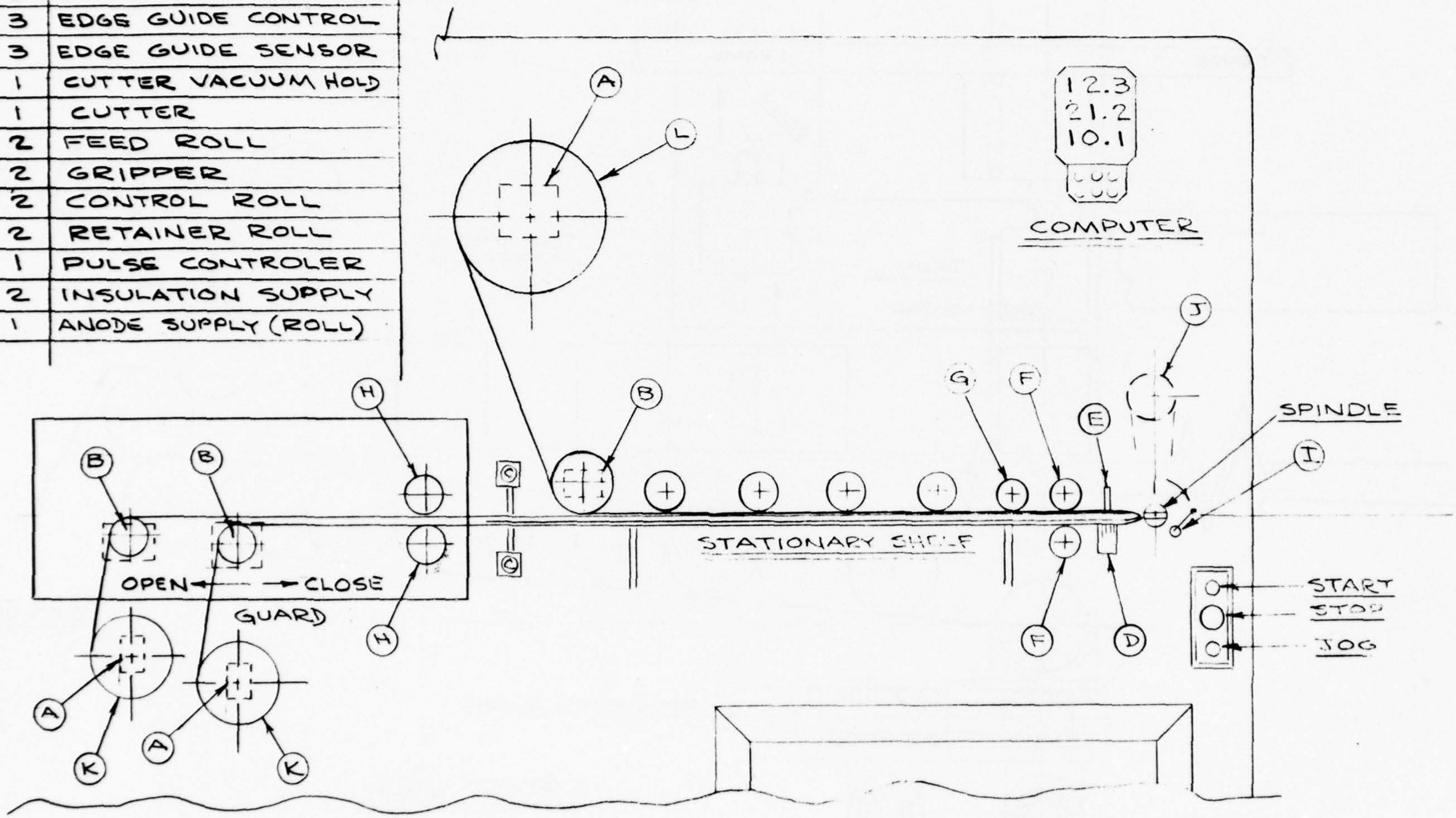
- Continuous tabbed anode material will be transferred from the accumulated inventory of the anode machine to the input of the core winder feed station.

- Two independent coils of separator will also be supplied to the input of the core winder feed station.

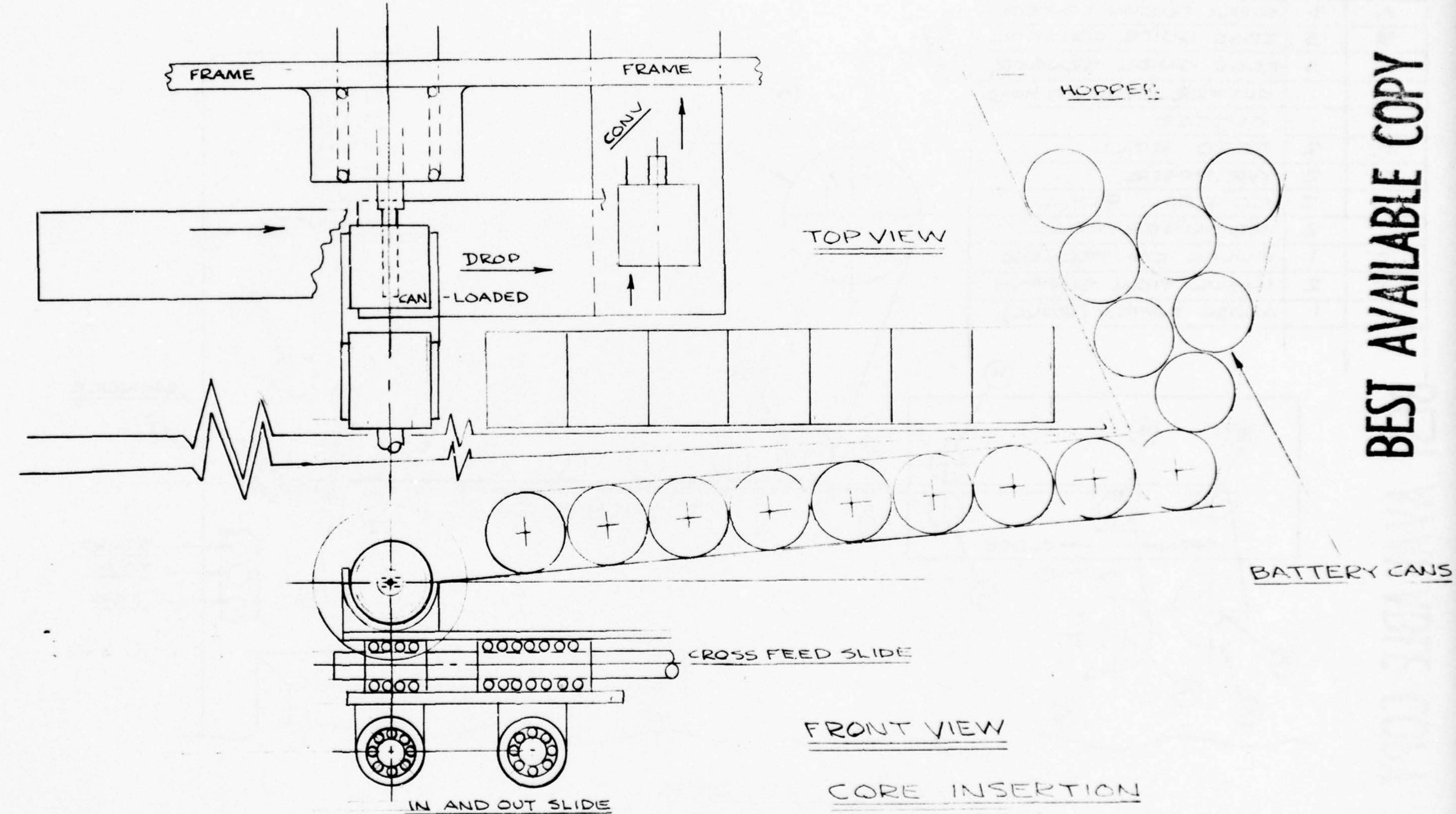
- The operator will place the precut cathode electrode into a holding fixture, as a channel, adjustable to various width positions. This channel will assure that the cathode is sufficiently straight to allow proper centering and registration within the separator.

- A feeding mechanism utilizing driven rolls and/or grippers will, upon demand, transfer the cathode from its holding fixture into its proper position with respect to the anode. A two position shuttle

SYM	No. REQ.	DESCRIPTION
A	3	SUPPLY TENSION CONTROL
B	3	EDGE GUIDE CONTROL
C	3	EDGE GUIDE SENSOR
D	1	CUTTER VACUUM HOLD
E	1	CUTTER
F	2	FEED ROLL
G	2	GRIPPER
H	2	CONTROL ROLL
I	2	RETAINER ROLL
J	1	PULSE CONTROLER
K	2	INSULATION SUPPLY
L	1	ANODE SUPPLY (ROLL)



CORE WINDER
FIGURE 5



CORE INSERTION
FIGURE 6

or an indexing series of holding fixtures will allow the operator nearly the full cycle time for placement of the cathode assembly.

- The above electrodes will be positioned in a flat horizontal plan to minimize the effects of gravity on the alignment of the electrode assembly prior to core winding. Edge guidance control and tension regulation will be provided as required.

CORE WINDING

- A multi-spindle winding unit adapts to the start of the winding of one core at the same time as the termination of the wind of the preceding core as well as stripping for insertion into the can.

- As the core wind on one spindle nears completion, a signal, possibly detection of the anode tab, will rotate the spindle holder thus bringing the next spindle into intimate contact with the two separator feeds to effect mechanical engagement and initiate a predetermined number of turns.

- The two separator feeds will be cut between the two spindles completed by utilization of a wiping device to control the tailing components.

- Upon completion of the separator cut, the other spindle will continue to wind with anode and cathode insertion in controlled sequence.

- The operator can now remove the completed coil and place it into the can. This operation can be mechanized by the addition of a can feed mechanism.

An evaluation of various automatic equipment manufacturers will be performed during the next reporting period to permit timely procurement of the required core winding equipment.

VII. ELECTROLYTE PREPARATION AND DISPENSING

SHUTTLE VALVE

A prototype electrolyte dispensing shuttle valve has been fabricated to permit evaluation within an operational electrolyte dispensing system. The dispensing shuttle valve will sequentially operate under the following cycles:

- PURGE MODE

  This cycle purges the line of residual electrolyte, contamination, etc.

- VACUUM MODE

  This cycle evacuates the cell to a predetermined level of vacuum.

- ELECTROLYTE FILL MODE

  This cycle dispenses a predetermined volumetric quantity of electrolyte into the cell.

- CLOSED MODE

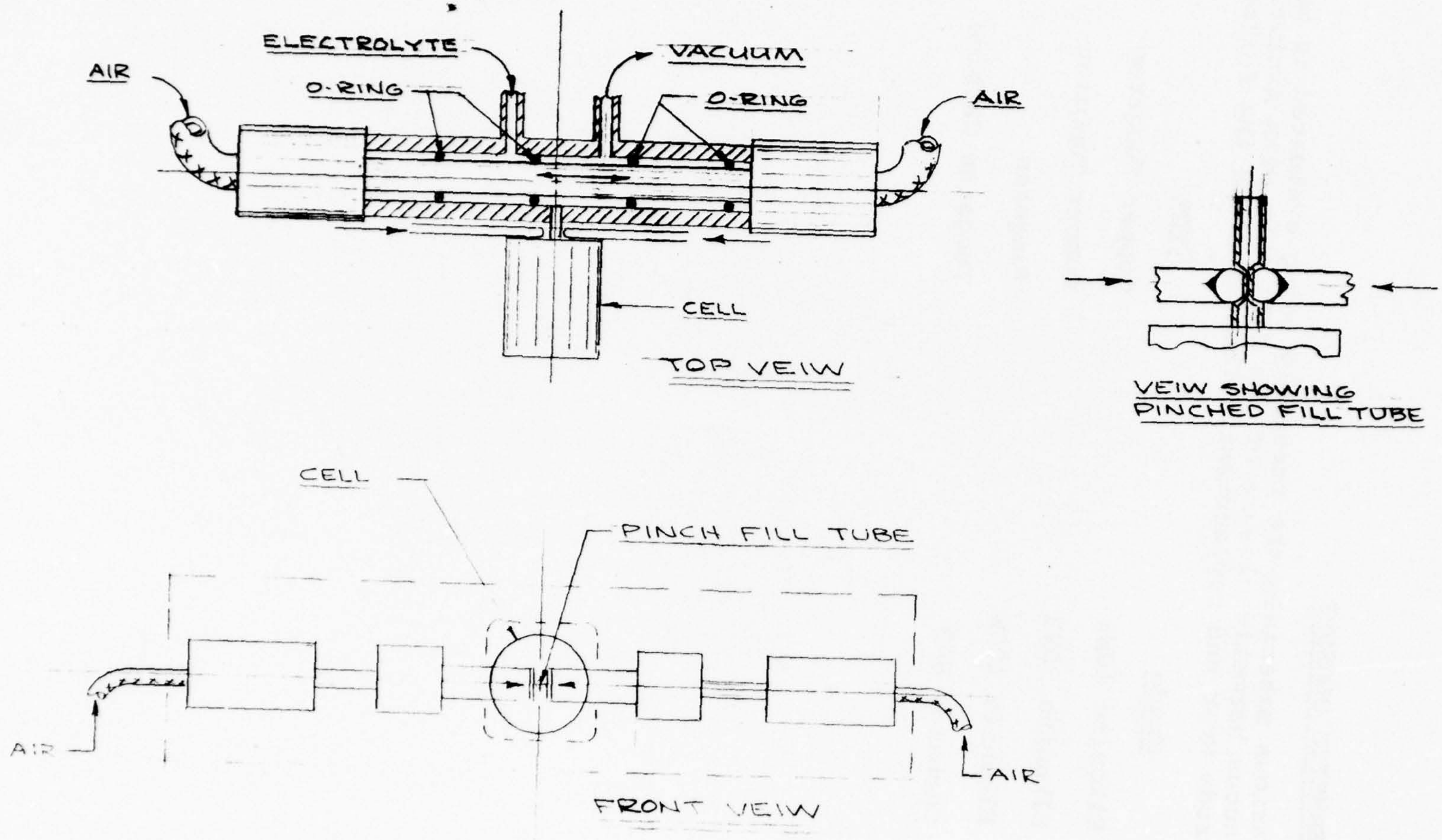
  This is a standby cycle which permits loading and unloading of the cell assembly.

The purging mode has been successfully implemented using a timed vacuum sequence to remove residual electrolyte from the lines immediately following the initial fill tube closure. This residual electrolyte is transferred to a cold trap station to condense the volatiles.

Evaluation of valve operation under the remaining modes will be performed during the next reporting period.

FILL TUBE CLOSURE

Automatic fill tube closure equipment will be incorporated into each dispensing station to permit temporary closure immediately following the electrolyte dispensing cycle. The finalized design concept of this dispensing station is shown in Figure 7. The jaw assembly will be actuated using a pneumatically operated hydraulic cylinder which provides a working pressure ratio of 16 to 1. This permits the attainment of relatively high hydraulic forces at the fill tube closure interface using a conventional air supply. Fabrication of the first prototype dispensing station will be accomplished during the next quarterly period.



SHUTTLE VALVE/CLIP-OFF STATION

FIGURE 7

HERMETIC CLOSURE

Various materials are presently being evaluated to permit continuous hermetic closure of the fill tube with minimal electrode wear and replacement. These include the following:

Grade	Type
Elkonite 10W3	Copper Tungsten
Elkonite 30W3	Copper Tungsten
Elkonite 100W	Tungsten
Corbaloy 883	Tungsten Carbide

VIII. HERMETIC SEAL AND CELL CLOSURE

During the fourth quarterly period, significant effort has been directed toward procurement and evaluation of the hermetic closure equipment which will be used to meet the required hardware production levels. The specific areas presently under evaluation are as follows:

- Cell Peripheral Weld
- Glass/Metal Seal Weld
- Hermetic Cell Storage

A. CELL PERIPHERAL WELD

1. Arc Welding

Hermetic closure of the cell periphery has been successfully implemented on all required cell types using a high speed arc welding process which has been installed at PCI. The peripheral weld system is presently equipped with a single weld torch head but has been designed to accommodate a dual station to permit welding of 5,000 units per day. The entire weld cycle is fully automatic and programmed to permit torch positioning up-slope, down-slope and weld current. The cell is vertically installed in an air operated three jaw chuck which is activated upon initiation of the weld sequence.

Weld speed is a direct function of the cell circumferential length; hence, the longest weld cycle occurs on the BA-5598/BA-5100 cell (1 1/2 inch diameter). Evaluation tests conducted on cell sizes ranging from .550 inch to 1.500 inch diameter have shown a complete process cycle (including part loading and unloading) of five and twelve seconds respectively. Actual production rates over extended periods of operation were observed to be approximately 1200 units per day. However, a substantial increase in rate capability is expected with increased operator experience.

Preliminary evaluation tests have been conducted on all required cell types to quantitatively determine the operating weld parameters which include weld current/time, rotational speed, shield gas flow rates, electrode gap and overlap control. Detailed specifications will be developed during the next quarterly period to document these parameters.

Evaluation of production peripheral weld yield rates over extended periods of operation has been somewhat hampered due to the presence of localized porosity at the welded joint interface on some cell sizes. This condition has been attributed to the following:

- Irregular gaps at the weld joint interface
- Variations in the physical configuration of the nickel plating present on the surface of the can and top shell assembly.

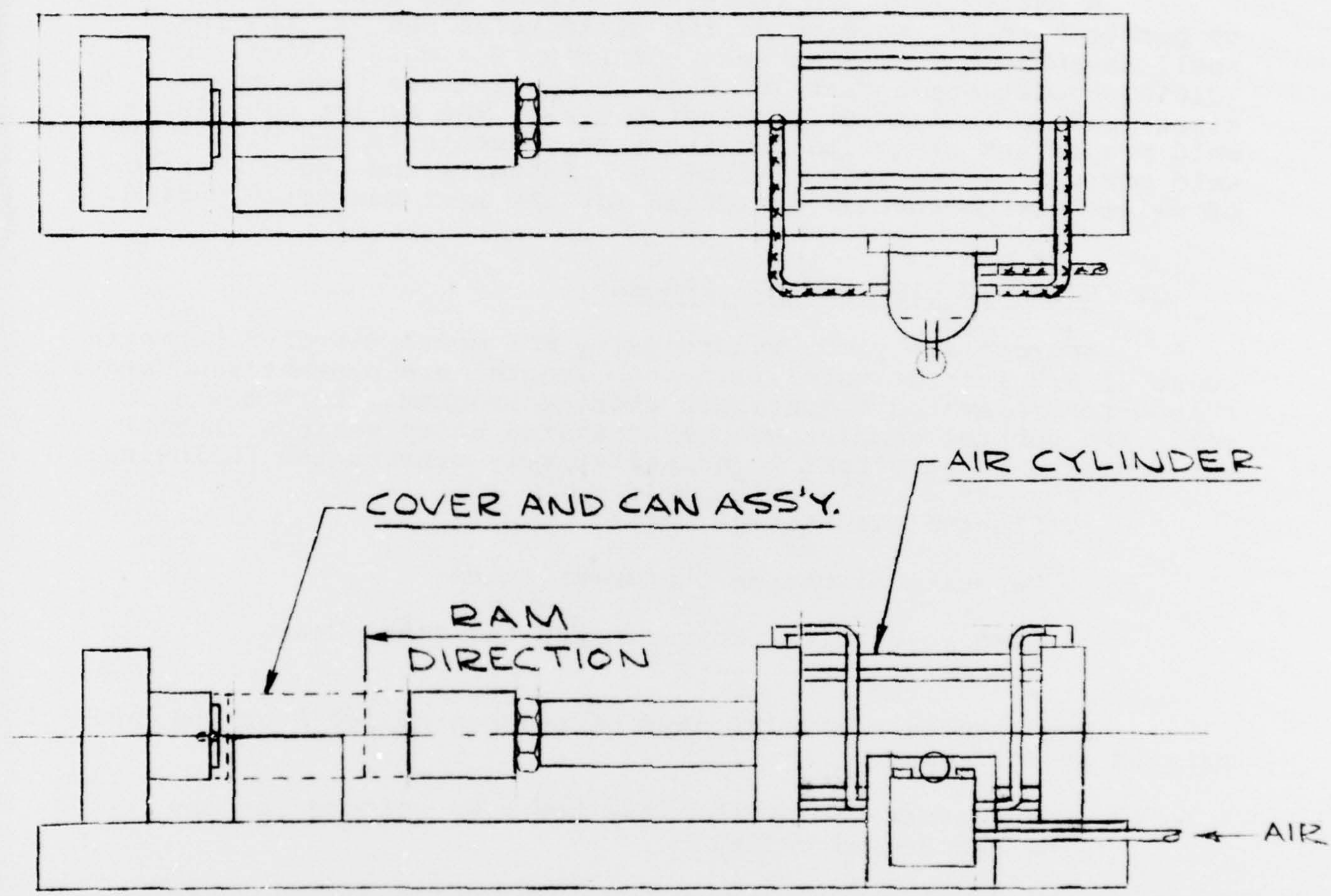
The interference fit of the top shell with respect to the can must be closely controlled to avoid irregular gaps which causes a bridging effect during peripheral welding and prevents the smooth flow of molten material across the joint. These gaps were primarily caused by mis-alignment of the top shell during insertion which caused the can to assume an out of round configuration. This condition will be minimized with the use of a pneumatic top insertion fixture as shown in Figure 8 . The fixture positions the top shell assembly with respect to the mating can to avoid cocking and mis-alignment during the interference press.

Various nickel plating processes including electroplating by Watts and sulfamate baths and electroless plating baths are presently being evaluated on both pre-plated and post-plated hardware to quantitatively determine their overall weldability and corrosion resistance characteristics.

Electrodeposits of nickel possess a wide variety of properties depending on plating bath composition, pH, current density and bath temperature. Control of the composition of the plating bath is probably the most important single factor contributing to the quality and uniformity of the nickel deposit. Initially, the bath must be carefully prepared to the desired composition and pH of the solution must be controlled within allowable limits in terms of both replenishing additions and degree of contamination by foreign substances.

Uniformity of thickness of electrodeposits is influenced by several factors including shape of parts, plating method, average current density, proximity to tank anodes and solution composition, pH and temperature. In barrel plating, the rotational speed of the load being plated also effect uniformity of plate thickness. PCI has established an optimal plating thickness requirement of 75 $\pm$ 25 microinch based upon experimental weld tests conducted on various size cell hardware. In addition, experimentation is currently being performed on electroplated hardware which has been treated in accordance with the following in an effort to improve overall ductility, weldability and adhesion characteristics:

- Post annealing at 1700 to 1800 °F in a reducing atmosphere.
- Pretreatment of a strike copper plate prior to electroless nickel plating.



PNEUMATIC TOP INSERTION FIXTURE

FIGURE 8

Upon completion of the above evaluations, a detailed specification will be developed to document the complete requirements for the nickel plating process. Evaluation of production arc weld equipment and techniques will continue during the next quarterly period.

B. GLASS/METAL SEAL WELD

A thirty (30) KVA resistance welder has been procured to permit hermetic welding of the glass/metal seal to the top shell assembly. The glass seal consists of a cold rolled steel (C1010) eyelet and a tantalum fill tube which are fused to a glass preform to form a compression seal. The eyelet contains a weld projection along its periphery to concentrate and direct the weld current at the joint interface. Installation and evaluation of welder performance is scheduled for the next quarterly period.

C. HERMETIC CELL STORAGE PROGRAM

Approximately one hundredfifty PCI model 660-5A-S hermetic cells (1 5/8 inch diameter, 5.5 inch length) are presently undergoing a long-term elevated temperature storage program. Both tests cells and control samples are being stored under various thermal environments in an effort to quantitatively measure the following:

- Electrolyte Leakage Rates
- Capacity Discharge Characteristics
- Electro-chemical Corrosion of the Glass Seal Assembly

The results after 180 days of storage at 160°F can be summarized as follows:

- No measureable weight loss has been detected on any of the stored cells.
- No significant loss of OCV (2.92 volts minimum) has been observed. Subsequent disassembly of sample cells did not indicate any evidence of electro-chemical corrosion of the glass seal assembly.
- Capacity results, as summarized in Table 4, have shown a slow gradual decline in cell capacity during 70°F discharge for cells stored at 160°F. However, no capacity loss has been observed on cells stored at room temperature. Additional data will be required to permit a quantitative determination of the magnitude of such capacity decreases.

The tests will be extended for a period of nine (9) months to obtain sufficient data verification to permit detection of any serious shortcomings.

TABLE 4

HERMETIC CELL STORAGE PROGRAM

CAPACITY DATA SUMMARY

LOAD 1.9 OHMS

STORAGE DAYS @ ROOM TEMPERATURE	0	30	60	90	120	180
AVERAGE SERVICE HOURS @ 2.0 VOLTS						
+70°F	17.5	16.1	18.2	18.2	18.2	18.7
-20°F	9.7	9.1	8.9	8.8	8.5	9.0
STORAGE DAYS @ 160°F	0	30	60	90	120	180
AVERAGE SERVICE HOURS @ 2.0 VOLTS						
+70°F	17.5	15.8	14.8	14.8	13.8	12.8
-20°F	9.7	10.2	11.5	9.6	11.4	8.3

IX. CONCLUSIONS

During the present quarterly period, effort has continued in accordance with the planned engineering objectives as defined in the revised PERT Chart. These objectives include the fabrication and evaluation of the required production equipment and the fabrication and evaluation of prototype hermetic cell and battery assemblies and components. The revised PERT Chart reflects the schedule changes necessary in the areas of cell and battery design, fabrication of engineering samples and procurement of the anode machine and 2nd core winder.

Several problem areas have been resolved with respect to peripheral seal welding, electroplating of hardware, resistance welding of the glass seal assembly and the implementation of a bottom fill structure especially for the BA-5567 and BA-5568 cells. In addition, a detailed Manufacturing Process Flow Chart was developed to define those areas requiring additional equipment or tooling and to permit integration of each fabrication process into an operational production line.

It has been necessary to modify the electrode configurations and internal construction of some cell designs as a result of additional electrical discharge performance data, theoretical internal volume analysis and re-evaluation of lithium/sulfur dioxide stoichiometric ratios. A maximum ratio of 1.2 will be implemented to minimize the hazards which may be experienced under certain abuse test environments.

Implementation of a hydraulic multipress designed to coin and swage the side wall vent structure at a fixed pressure rather than a fixed position appears to be the most desirable technique to minimize the variations of coined thickness at a tolerance of $\pm$ .0005 inch. Hydraulic pressurization tests have confirmed a distribution value of $\pm$ 50 psi for large diameter cells and $\pm$ 75 psi for small diameter cells at a median pressure of 400 psig. The quantitative effects of lubricity and material temper will be examined in an effort to finalize the vent structure fabrication process.

Continuous anode fabrication is considered to be the preferred approach because of difficulties encountered during manual handling, cutting, storage and transfer of the anode due to the extreme ducility and adherence characteristics of lithium foil. Such physical distortion of the anode/tab assembly results in significant delays during subsequent electrode loading within the core winder feed station. Design concepts have been finalized and evaluation of various automatic equipment manufacturers will be accomplished during the next quarterly reporting period.

Additional prototype cathodes are presently being fabricated and evaluated utilizing large cathode batches over extended periods of operation to determine machine parameters for various cathode thicknesses. It is advantageous to obtain the desired cathode thickness prior to its entry within the sizing roller to avoid subsequent material densification and resulting porosity variations. An acceptance tolerance range of $\pm$ .0025 inch has been established for the continuous cathode fabrication process. Cathode drying will be accomplished utilizing radiant heat energy under a predetermined thermal profile to remove excess moisture prior to the slitting operation. Continuous automatic removal of the support substrate from the formed cathode and its interface with the fabrication process, will be evaluated during the next quarterly period. Selective removal of cathode material along the width of the conductor grid has been successfully accomplished using a pressurized air impingement to permit subsequent electrical attachment of the conductor tab.

Difficulty has been encountered with alignment and registration of the cathode within the separator during the core winding operation. Alignment guides have been installed along the feed station track to facilitate anode and cathode insertion and permit positive placement within the nibs of the drive rollers. The design concept for the 2nd semi-automatic core winder has been finalized and evaluation of various automatic equipment manufacturers will be accomplished during the next reporting period.

A prototype electrolyte dispensing shuttle valve has been fabricated to permit evaluation within an operational electrolyte dispensing system. This valve will operate under four sequential cycles, manely, purge, vacuum, electrolyte fill and closed modes. The purging mode has been successfully implemented to remove residual electrolyte from the lines immediately following the initial fill tube closure which avoids electrolyte contamination of the top surface of the cell. This is necessary to avoid subsequent potential resistive short circuits due to electrochemical galvanic corrosion at the insulating glass seal interface. Initial fill tube closure will be accomplished using a pneumatically operated hydraulic cylinder to obtain the required clamping pressure necessary for this sealing operation.

Peripheral weld tests conducted on cell sizes ranging from .550 inch to 1.500 inch diameter have shown a complete process cycle (including part loading and unloading) of five and ten seconds respectively. Evaluation of production peripheral weld

yield rates over extended periods of operation has resulted in some difficulty to the random presence of localized porosity at the welded joint interface. This condition has been attributed to irregular gaps at the weld joint and observed variations in the physical configuration of the nickel plating present on the surface of the can and top shell assembly. Corrective action is presently underway to control the alignment of the top shell during the interference press operation and to minimize plating variations by imposition of a detailed specification composition and pH, current density and acceptable contamination levels. Procurement and installation of a thirty (30) KVA resistance welder is presently underway to permit production hermetic welding of the glass/metal seal to the top shell assembly.

X. PROGRAM FOR 5th QUARTER

The proposed program for the next quarterly reporting period will include the following:

- Continued fabrication and evaluation of hermetic cell assemblies and review of equipment fabrication status.
- Sub-contractor evaluation for the fabrication of the automatic anode machine and 2nd core winder.
- Production fabrication and evaluation of cathodes using the continuous cathode equipment over extended periods of operation.
- Evaluation of resistance weld equipment for production glass/metal seal welding.
- Fabrication and evaluation of cell engineering samples and prototype batteries.
- Completion of cell/battery drawing packages and process specifications.

XI. IDENTIFICATION OF PERSONNEL

The following additional personnel are presently involved in the subject program:

Richard J. Tarpey

Mr. Tarpey has sixteen years experience as Quality Control Manager with Sonotone Corporation, Cold Springs, NY where he supervised a staff of Quality Control engineers and foreman in the manufacture of various nickel cadmium batteries. In addition, he has six years experience as Sales Manager and Contract Administrator with Marathon Corporation responsible for product compliance to customer and governmental specifications. In his present position as Quality Control Manager, he is responsible for implementing and monitoring all required quality assurance inspection procedures and product configuration control for battery manufacturing, assembly and test.

The labor hours expended during this quarterly reporting period are as follows:

Dr. Stewart M. Chodosh	54 hrs.
Contracts Administrator/ Program Manager	
Martin G. Rosansky	333 hrs.
Senior Engineer	
Thomas M. Watson	333 hrs.
Senior Engineer	
Anandaram Joshi	32 hrs.
Test Engineer	
Julius Cirin	201 hrs.
Technician	
James Harris	77 hrs.
Technician	
Ralph Mantello	385 hrs.
Technician	

Prakash Jog 37 hrs

Engineer

Stanley Lewin 33 hrs.

Operations Manager

XII. PUBLICATIONS AND REPORTS

No publications or reports were issued during this present quarterly period.

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